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RESEARCH MEMORANDUM

SOME DESIGN REQUIREMENTS FOR A STEADY-STATE FORCE MODEL

David M. Rodney

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A handwritten signature in dark ink, reading "Lewis R. Cabe". The signature is written in a cursive, flowing style.

Lewis R. Cabe

Director

Manpower and Training Program

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ABSTRACT

This research memorandum describes the approach being used to develop an executable and cost-effective steady-state force. The issues that need to be incorporated into the derivation of a steady-state force model are addressed. The memorandum highlights, by way of examples, numerous ways in which personnel policies and billet structure may be inconsistent, thus making it impossible to execute all policies simultaneously and obtain the required force structure.



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EXECUTIVE SUMMARY

BACKGROUND

In the current fiscal climate there are many pressures to save money through more efficient force management. In response to tasking from the Deputy Chief of Naval Operations for Manpower, Personnel and Training (OP-01), CNA is investigating the consistency of Navy policies, compensation levels and billet structure as a foundation for the determination of cost-effective steady-state force structures. Deriving consistency between billet structure and personnel policies, leading to an executable force structure, is a complex process. Personnel policies and billet structure are frequently inconsistent, making it impossible to execute all policies simultaneously and obtain the required force structure.

OBJECTIVE

The objective of this research memorandum is to define and provide insight into the variety of analytic issues that need to be addressed and incorporated into a steady-state force model.

SUMMARY

This memorandum describes the approach being used to develop an executable and cost-effective steady-state force. The memorandum identifies and discusses issues that must be included in a steady-state force model. Structural equations that define the force and assumptions and limitations that underlie such a model are included. Implementation techniques are not addressed.

Examples of problems that may occur in personnel management if policies are out of line with billet structure are discussed. Examples of inconsistent policies also are provided to highlight policy interactions and show how they may easily lead to unexecutable force structures.

The following issues are addressed:

- The process of determining requirements and how it leads to large variations in pay grade structure between the ratings
- The necessity for a correct balance between sea and shore billets to provide reasonable sea/shore rotation
- The need for sufficient junior personnel to meet requirements for more senior personnel in the future

- Analysis mainly at the level of ratings, with more detail (i.e., NECs) required for some communities
- Analysis at a total Navy level to address topics such as end-strength constraints
- Promotion policy
- Compensation policy
- Sea/shore rotation policy
- The need for a force structure that is both attainable at a point in time and maintainable over a period of time
- Structuring manpower requirements in the context of a risk-averse and conservative organization that wants to minimize the possibility of degrading personnel readiness while conserving personnel expenditures.

Techniques to determine whether a given set of policies and billets are executable are discussed. Finally, an approach to building a steady-state force is outlined.

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INTRODUCTION

The current fiscal climate includes many pressures to save money through more efficient force management. In particular, the "aging of the force" has increased Military Personnel Navy (MPN) expenditures, and questions have been raised about the need for and cost-effectiveness of a more senior force. The prospect of greater personnel readiness and cost savings has motivated efforts to obtain more efficient force structures.

The Deputy Chief of Naval Operations for Manpower, Personnel and Training (OP-01) has tasked CNA to conduct a study that would help determine the optimum personnel mix in the enlisted force to maximize readiness and minimize costs. The concept of an "optimum force" embodies the search for an efficient force structure. Issues in the development of such a force include desirable pay grade and length of service distributions and necessary accession and retention rates. In order to find the optimal way to man the Navy it would be necessary to relate personnel resources to readiness in a precise manner. Since such a capability does not now exist, a truly optimal force cannot be derived. However, by accepting official guidance regarding seniority requirements at the unit level and by not attempting to measure and analyze personnel productivity, the internal consistency of billet structure and Navy policies can be investigated to ensure that operations are efficient and cost-effective. Consequently, CNA is conducting a study that has the following objectives: evaluate the consistency of Navy policies, compensation levels, and billet structure; determine a least-cost force structure and the policies and compensation needed to maintain it, given a set of unit-level constraints on billet structure; and determine a set of policies that will make possible a timely and cost-effective transition from today's inventory to a target inventory without adversely affecting personnel readiness. Given the changing nature of manpower requirements, the target inventories and transition forces will need to be recomputed from time to time. Thus, the methods and tools by which the results are obtained are as important as the results themselves.

This research memorandum describes the approach being used to develop an executable and cost-effective steady-state force. (Transition issues will be addressed in another report.) Structural equations to define the force are presented, as are the underlying assumptions and limitations of such a model. The complexity of deriving consistency between billet structure and personnel policies that would lead to an executable force structure is described. Examples of inconsistencies between policies and billet structure are provided, illustrating how inconsistencies can make it impossible to execute all policies simultaneously and obtain the required force structure. Cost-effectiveness is surely predicated on consistency between personnel policies and billet structure. Thus, a major part of the following discussion is concerned with force structure executability.

The modeling of a force structure requires analysis of the behavior and interaction of many variables. For example, the relationships between promotion opportunity, continuation rates and compensation must be understood. Many such relationships must be considered, some are more significant than others, and knowledge about these relationships is less than perfect. In an ideal

world, the model developed would be very complex, formulae that precisely describe the interactions between variables would be "plugged in," and the problem would be solved on an extremely large computer. In the practical world, such an approach will inevitably lead nowhere. For example, an ideal model would allow tradeoffs between quantity and quality in personnel; three first-class petty officers might be interchangeable with four second-class petty officers, for example. However, knowledge of such relationships is extremely limited, and it is not currently possible to model tradeoffs of quantity versus quality. Thus, any practical model will contain limitations.

The accuracy and feasibility of the model may increase as the number of assumptions and limitations is increased. However, the area in which the model can be used will shrink as the number of assumptions is increased. For example, an executable, cost-effective force structure could be based on current sea/shore rotation ratios. This would certainly make the modeling task more tractable, but it would ignore the possibilities that arise from variations in sea/shore rotation, a central policy in Navy personnel management. Thus, a balance must be sought between what is necessary for an all-encompassing approach to determining Navy manpower requirements and what is feasible. Inevitably, assumptions, inaccuracies, and subjective judgements will lie behind whatever model is developed. These limitations must be understood in order to appreciate the value and caveats that surround any model output.

The model must consider all major personnel management policy tools and all of their significant effects on force structure. This study examines the interactions between policies, with the goal of determining consistent and efficient policies. If a policy or its effect is ignored, the assumption is that it does not vary or is irrelevant in the situations studied. Due to the many interactions between policy variables and force structure, such assumptions are often erroneous. For example, a change in time-in-service requirements for promotion will have two different significant effects on force structure. The first and obvious effect is to change the admissible range of longevity in certain pay grades. For example, a change in time-in-service requirements might make it possible for a member to become an E-7 in 11 years as opposed to 12 years of service. The second effect will be to change promotion opportunity, which will affect continuation rates, and hence force structure, due to the implied differences regarding earnings and status. Because the effects on promotion opportunity are complex and not easily modeled, there may be a tendency to ignore them in order to make the problem more tractable. But this implicitly assumes that a change in promotion opportunity will not noticeably affect continuation behavior, which is untrue. There are systematic variations in continuation behavior between pay grades. Consequently, a change in promotion opportunity is likely to have an observable impact on continuation rates. Figure 1 provides an example of this situation and shows how continuation rates varied between pay grades E-5 to E-7 during fiscal year 1988. Thus, for a model to be realistic, it must capture all the major dynamics of force structure. This memorandum endeavors to describe these major dynamics and thus define the scope of the required modeling effort.

This research memorandum identifies and discusses only the issues that need to be included in a steady-state force model; implementation techniques are not addressed.

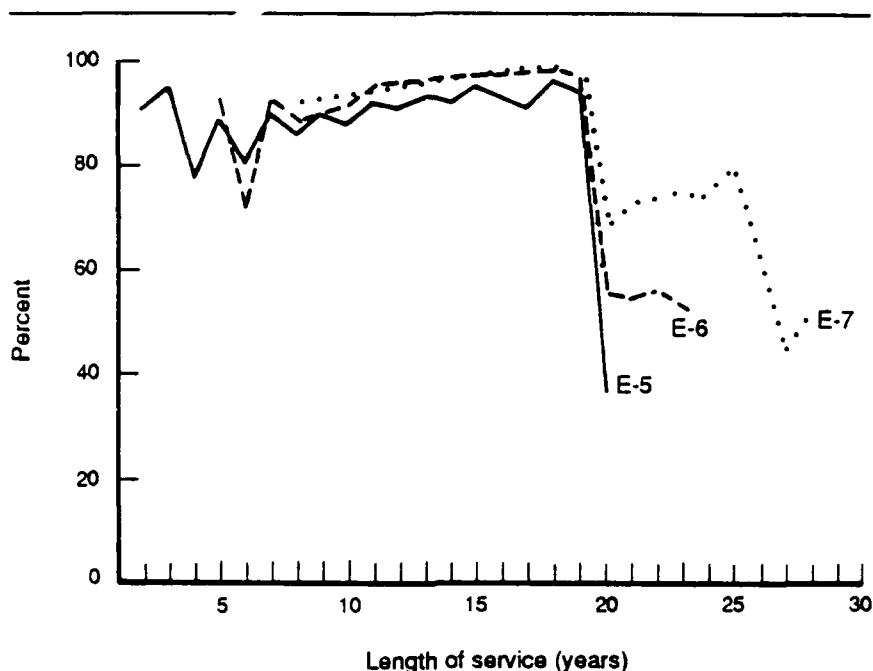


Figure 1. Continuation rates for E-5 to E-7, September 1987 to September 1988

PROPERTIES OF FORCE STRUCTURE

Model development begins by taking a broad view of the determination of manpower requirements. The development of force structure may be considered as a process initiating from statements of threats: threats lead to missions; missions lead to ships and squadrons; ships and squadrons lead to at-sea manpower requirements; sea manpower requirements plus personnel policies and compensation lead to shore requirements and force structure; variations in policy and compensation lead to a cost-effective force; and current inventories and a cost-effective force lead to a transition force. This perspective provides some key observations regarding the study methodology.

First, force requirements are based on an explicit, fixed set of Navy missions, which are usually current missions. The impact of mission alterations is addressed by considering the consequences of such actions as a reduction in OPTEMPO or the removal of a carrier battle group.

Second, the methodology follows the process in which requirements are logically defined at a unit level. Navy policies and compensation apply to the aggregation of these requirements and result in force structure. The search for an executable, cost-effective force entails an analysis of interactions between the process of determining requirements at the unit level and the application of policies for the Navy as a whole (ALNAV). Broad issues in manpower planning and management may conflict in a variety of ways with requirements determined at the unit level. For

example, billet grades are unconstrained during requirements determination, leading to significant variations in pay grade distributions between ratings. Table 1 provides an example of such variations by displaying the percentage of all petty officer billets that are in grades E-7 to E-9, for a number of ratings. Undoubtedly, the work requirements of different ratings legitimately lead to variations in grade structure. However, there are policies and legislative limits placed on overall Navy grade structure. Consequently, if one rating has a "senior" pay grade structure, then another rating will necessarily have a "junior" grade structure. From the perspectives of career development and equity, variations of the type observed in table 1 may not be desirable. For example, a rating with a "junior" grade structure may offer fewer promotion opportunities, hence low continuation rates and lack of personnel longevity.

Finally, some billets exist to support other billets. Requirements may be divided into two categories:

- *Primary*—manning of ships, squadrons, and selected shore facilities such as communication sites
- *Secondary*—manpower for the facilities that exist for the support of primary activities (e.g., Navy Manpower Personnel Command, Ship Intermediate Maintenance Activities).

Table 1. Variations in rating seniority (based on FY 1988 authorizations)

Rating	Percentage of petty officer billets in grades E-7 to E-9
Quartermaster (QM)	21.5
Operations specialist (OS)	11.5
Personnelman (PN)	19.1
Mess management specialist (MS)	12.8
Machinist's mate (MM)	13.4
Air traffic controller (AC)	12.3
Hospital corpsman (HM)	15.9
ALNAV	14.9
Source: Enlisted billet file	

A variety of official statements address how one can, should, or does staff the primary and secondary activities. The methodology will obtain cost-effective force structures based on a number of ways of manning the primary activities. Because a large majority of the primary

activities are ships and squadrons, for ease of expression *sea-manning* and *manning of primary activities* are used synonymously. The manning of secondary activities fulfills three purposes. First, the job presumably needs to be performed, although not necessarily by military personnel. Second, the job may provide shore duty required for sea/shore rotation. Third, the job may be necessary from the perspective of pay-grade distribution. For example, it is not practical to have a rating with 1,000 E-6 billets and 20 E-5 billets, because "enough" E-5s are needed to be promoted to E-6s in a few years. Thus, the analysis of manning the secondary activities must consider the requirements of the particular job, as well as "rotational" and "agricultural" requirements of the rating as a whole. (*Agricultural requirements* refers to needs for junior personnel solely to provide sufficient senior personnel sometime in the future.)

The desired cost-effective force structure will be in a steady state: that is, the force structure will not vary from one year to the next. This means that compensation levels, promotion policies, and other personnel policies will lead to continuation behavior that makes the force self-sustaining. There are many constraints to a steady-state force structure, as will be described below.

Much of the analysis will be done at the level of ratings, and ratings will be considered independently. However, there are limitations to this approach. First, the flow of apprentices into the ratings and the flow of various ratings into "compression" ratings that only exist at senior pay grades must be modeled. (The number of Navy personnel who actually change careers and switch ratings is rather small. It is unclear how much one should or can model career changes in the Navy.) Also, some aspects of force structure cut across all ratings and all the ratings must be considered simultaneously to adequately model the situation. For example, many shore billets can be manned by any petty officer (e.g., recruiting billets). In the context of a desired least-cost force structure, it is not at all clear how one decides to divide such billets across the ratings, and the ratings must certainly be seen in a unified manner to address this issue.

Finally, analysis at the level of ratings will not suffice in all cases. Many Navy Enlisted Classifications (NECs) will have to be given special consideration, because many communities of personnel are defined by NECs, and have distinct career patterns that require the same type of personnel management as is applied to individual ratings. Nuclear-trained petty officers are an obvious example.

Navy management controls force structure in many ways. The methodology concentrates on the most significant three: compensation; promotion; and sea/shore rotation. Each of these three policy tools profoundly affects force structure and behavior. Many econometric models have been built to quantify the relationships between these variables and retention. They have resulted in significant though incomplete and imprecise knowledge. Since the development of an executable and cost-effective force will be based on the relationships between the above policies and retention, it is important to understand both the strengths and weaknesses of these econometric models to appreciate the value of any force structure results.

MODEL CHARACTERISTICS

The approach to the development of an executable, cost-effective force structure is described in this section. First, the notation of some basic concepts is introduced.

The inventory must be described in three dimensions: skill, pay grade, and length of service (LOS). The inventory is thus represented by a three-dimensional array, INV (skill, pay grade, LOS). Requirements can be split into two parts—sea and shore requirements, which are represented by SEA(skill, pay grade, LOS) and SHORE(skill, pay grade, LOS), respectively. Evidently,

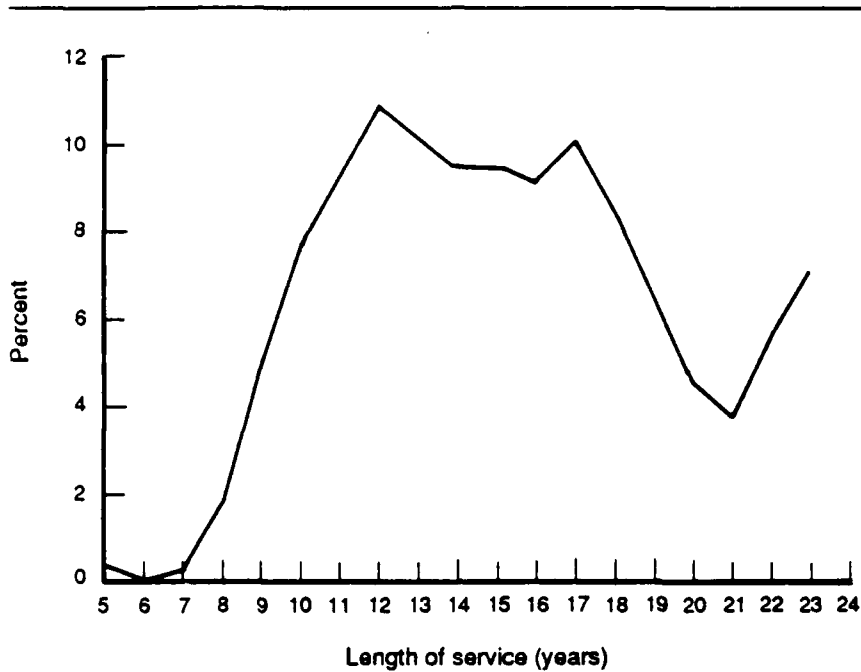
$$\text{INV}(\text{skill, pay grade, LOS}) = \text{SEA}(\text{skill, pay grade, LOS}) \\ + \text{SHORE}(\text{skill, pay grade, LOS})$$

There are three policies to consider: compensation, promotion, and sea/shore rotation. Compensation includes all facets of compensation (regular military compensation, special and incentive pays, retirement accrual, etc.). Compensation varies with skill, pay grade, and length of service.

Promotion policy specifies minimal and maximal length of service for each pay grade, constraints on the pay-grade distribution, and rules governing desired promotion opportunity. The required minimal length of service for the various pay grades are specified through time-in-grade and time-in-service requirements. The maximal admissible longevity within a pay grade is specified through "up or out" policies. In the context of obtaining desirable force structures, there is no reason why promotion policy should not vary across skills. Current promotion policy shows indifference to longevity once personnel are eligible for promotion. Thus, the fraction of eligible personnel promoted from a particular pay grade does not systematically vary with length of service. Figure 2 provides an example of this situation by showing the rate of promotion from E-6 to E-7 for different LOS cells. The figure shows that for a broad range of longevity (approximately 10 to 18 years of service), there was comparatively little variation in the fraction of personnel promoted between 1987 and 1988. However, it would be interesting to understand how force structure would vary if this policy is altered. Thus, a steady-state force model should allow promotion policy to vary by skill, pay grade, and LOS.

Sea/shore rotation policy, as described in the Enlisted Transfer Manual [1], specifies the length of sea and shore tours. These tour lengths vary across skills and between pay grades within skills. Moreover, sea/shore policy specifies the maximum amount of time personnel should continuously be on sea duty and discourages back-to-back sea tours. Inconsistencies between such policies and billet structure may make it difficult, if not impossible, to correctly man all billets. Consider, for example, the Operations Specialist (OS) rating. Table 2 shows authorized OS billets disaggregated by type of duty. As the table shows, a large majority of

billets for pay grade E-5 are at sea. But tour rotation policy and promotion rates are such that a majority of E-5 OSs are serving their first shore duty. Consequently, manning these E-5 OS billets is a recurring problem.



Source: Enlisted master files

Figure 2. Percentage of all E-6s in LOS cells, promoted to E-7, FY1987 to FY1988, regardless of eligibility

Table 2. OS authorization for FY 1988 by type of duty

Pay grade	Sea duty	Shore duty
E-4	3,129	411
E-5	2,250	870
E-6	1,190	1,278
E-7	220	536
E-8	249	100
E-9	32	52

SOURCE: Enlisted billet file

A change in a compensation, promotion, or rotation policy alters the behavioral patterns of personnel. An initial objective of force management is to establish policies and manpower requirements that are *feasible*. In the work that follows, a force structure represents not only the manpower requirements, but also the personnel policies that make it possible to obtain and manage the required personnel.

Therefore, a *force structure* is all of the following:

- SEA (skill, pay grade, LOS)
- SHORE (skill, pay grade, LOS)
- compensation policy
- promotion policy
- sea/shore rotation policy.

Although it is unusual to describe personnel policies as a part of force structure, as opposed to being actions that affect force structure, an essential concept of this work is that personnel alignment and policies may not be considered independently. Effective management demands not only precise specification of requirements but also descriptions of policies that enable the Navy to meet requirements.

An almost endless number of different force structures could be specified, but not all of them will be meaningful, because many force structures could not exist. Consider the following unrealistic example: Specify a Navy of 500,000 personnel and a compensation policy wherein personnel earned no more than \$500 per month! One could not reasonably expect to attain such a force structure. So, not all force structures are attainable. If a force structure is attainable, it is called *feasible*.

Two kinds of feasibility must be addressed. The first is *point-in-time feasibility*, or the question of whether it is possible to obtain a certain force structure, even if only for a brief period. The second is *steady-state feasibility*, the question of whether a force structure is both attainable and maintainable. For example, it is possible to attain an inventory which has 500 personnel with eight years of service and 10,000 personnel with nine years of service, but such a force structure could not maintain itself from one year to the next. The definition of a *feasible* force structure given above refers to point-in-time feasibility. Initially, properties of feasible force structures need to be examined. Once this has been completed, attention should be turned to the more stringent condition of *steady-state feasibility*.

In the study of *feasible* force structures—that is, the possibility of attaining a force structure, if only briefly—analysis focuses on whether a particular set of policies will support a

given inventory. For example, suppose the objective is an inventory that corresponds to FY 1988 endstrength. The policies in place during 1988 enabled the Navy to attain its FY 1988 endstrength. But many other sets of policies would have enabled the Navy to attain the same endstrength, and all of them correspond to a *feasible* force structure. A feasible force structure is dependent on force structure at a previous point in time. For example, the policies in place in FY 1988 enabled the Navy to attain its FY 1988 endstrength, based on the inventory that existed at the end of FY 1987. If a markedly different inventory had existed at the end of FY 1987, it may not have been feasible to obtain the end FY 1988 inventory no matter how policies were specified. In order to understand whether it is possible to transition from one inventory to another, it is necessary to have inferential models of the relationships between personnel policies and retention.

A *steady-state feasible* force structure is one that is both attainable and maintainable from one year to the next. These criteria impose some strong restrictions on the inventory. In particular, the continuation rates must maintain the inventory from one year to the next. Because the Navy "grows" its own and does not access significant numbers of experienced personnel, Navy longevity profiles have a well-known shape: the number of personnel in any length-of-service cell must be at least equal to the number of personnel in the succeeding LOS cell. Moreover, the size of successive LOS cells determines continuation rates and must be consistent with specified policies. For example, suppose there are 10,000 personnel with 15 years of service and 9,000 personnel with 16 years of service. Then compensation policy, etc., must be such that 90 percent of personnel with 15 years of service remain in the Navy until the next year. Figure 3 shows a length-of-service distribution that could arise in a steady-state force structure.

A steady-state feasible force may be better understood by a description of the force structure equations that exhibit the flows of personnel from one year to the next. The flows are described in the following equation by arrays that are indexed by skill (*s*), pay grade (*pg*), length of service (*LOS*) and time (*t*) (i.e., year).

$$\begin{aligned} \text{INV}(s, pg, LOS + 1, t + 1) = & \{ \text{INV}(s, pg, LOS, t) \\ & - \text{PROM_OUT}(s, pg, LOS, t) \\ & - \text{DEM_OUT}(s, pg, LOS, t) \\ & - \text{LAT_OUT}(s, pg, LOS, t) \} \\ & * \text{CR}(s, pg, LOS, t) \\ & + \text{PROM_IN}(s, pg, LOS, t) \\ & + \text{DEM_IN}(s, pg, LOS, t) \\ & + \text{LAT_IN}(s, pg, LOS, t) , \end{aligned}$$

where INV = inventory, PROM_OUT = promotions out of a pay grade, DEM_OUT = demotions out of a pay grade, LAT_OUT = personnel flowing out of a skill, CR = continuation rates, PROM_IN = promotions into a pay grade, DEM_IN = demotions into a pay grade, and LAT_IN = personnel flowing into a skill.

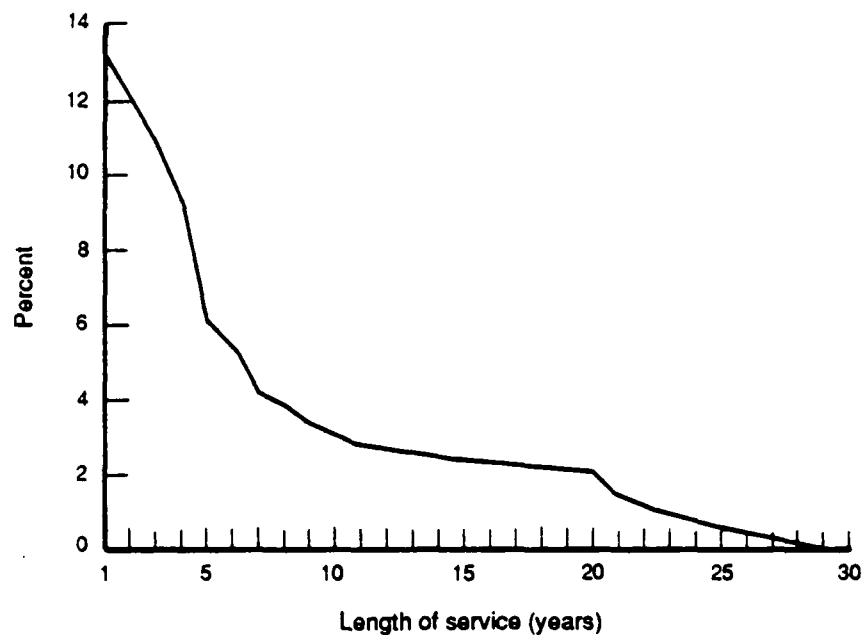


Figure 3. Length-of-service distribution in a steady-state force structure

The above equation is not exact because continuation rates for personnel who are promoted, demoted, or make a lateral move are not specified. Knowledge of such continuation rates is sparse, and it would be impractical to include such rates in a model. The implicit assumption is that all such personnel will remain in the Navy for a year (i.e., a continuation rate of 100 percent). This is reasonable when considering promotions and possibly lateral moves, but it is unrealistic when considering personnel who have been demoted. Most personnel who are demoted are in the junior pay grades, and many will leave the Navy within a short time. Thus, it is expeditious to remove demotions from the structural equations and assume that such are personnel losses from the Navy. Additional support for this approach is that since little is known about how the number of demotions would vary with policy, little is gained by including this variable in a model.

In a steady-state model, the number of personnel in any part of the inventory is invariant over time. Thus, removing demotions and the time dimension from the above equation provides the following description of steady-state flows:

$$\begin{aligned}
 \text{INV}(s, \text{pg}, \text{LOS} + 1) = & \{ \text{INV}(s, \text{pg}, \text{LOS}) \\
 & - \text{PROM_OUT}(s, \text{pg}, \text{LOS}) \\
 & - \text{LAT_OUT}(s, \text{pg}, \text{LOS}) \} \\
 & * \text{CR}(s, \text{pg}, \text{LOS}) + \text{PROM_IN}(s, \text{pg}, \text{LOS}) \\
 & + \text{LAT_IN}(s, \text{pg}, \text{LOS}) .
 \end{aligned}
 \tag{1}$$

Equation 1 is central to the study of a steady-state force. All of the arrays in equation 1 will vary as policies are varied. However, in order for a force to be in a steady state, an equilibrium, as described in equation 1, must hold. In this sense, equation 1 provides strong constraints to a force structure being *steady-state feasible*.

Another analytical issue in the study of *feasible* force structures is the consistency of policies. It is quite easy to specify a set of policies which has in-built inconsistencies. For example, consider a simplified force structure of three pay grades, where personnel serve for not more than three years. Further suppose that pay-grade requirements, compensation policy, and promotion policy have been specified. Then the following situation might occur, as shown in table 3.

Table 3. Hypothetical force structure

	E-1	E-2	E-3	Total
LOS 1	*			200
LOS 2		*	*	150
LOS 3		*	*	150
Total	175	175	150	

The table shows column totals for the number of personnel in each pay grade. The row totals show the number of personnel in each LOS cell that would result from the compensation and promotion policies. Finally, the asterisks represent the combinations of pay grade and longevity that are allowed by the promotion rules. In this example, E-1 personnel may be in the first LOS cell but not in the second LOS cell, etc. It is easy to see that it is impossible to allocate personnel to the above matrix in a manner that is consistent with both the row and column totals. This situation is analyzed more fully in [2], which contains a description of the conditions that make it impossible for constraints on pay-grade structure, longevity, and promotion policy to be satisfied simultaneously. In particular, [2] shows that "up or out" policies that are too stringent are precisely the conditions under which a desired force structure will not be unexecutable.

The analysis in [2] is based on an algorithm that iteratively converges on a force structure that meets force structure specifications to the greatest possible degree. This approach to building a steady-state inventory seems to be a fruitful, automated way of investigating force structure and may provide a key element in the development of a least-cost force.

The development of force structure has a logical flow and the modeling process needs to capture this flow. With this in mind, the following sequence of events is suggested for the development of a least-cost force.

1. Sea manning requirements, by skill and pay grade, are obtained from ship manpower documents (SMDs) and squadron manpower documents (SQMDs). (Alternately, if authorizations are to form the basis of sea manning, then the billet file will provide sea manning information by skill and pay grade.)
2. Feasible steady-state forces are built for individual skills. These inventories are obtained by specifying sea/shore rotation, promotion, and compensation policies and computing the shore billets required to complement the sea billets and produce a steady-state inventory. In step 1, manpower was described by pay grade and skill. During step 2 the dimension of longevity is added.
3. Step 2 derived numerous steady-state inventories that specify shore manpower required for rotational and agricultural purposes. These specifications of shore manpower need to be compared with official statements on shore manpower needs to evaluate the adequacy of the shore manning generated for rotational and agricultural purposes. If the steady-state inventories are perceived to provide inadequate shore support, then either the shore manning should be increased or the possibility of recruiting civilians to fill billets should be pursued. To increase shore manning, policies would have to be respecified to derive a new steady-state force that has the desired number of shore billets.
4. The above work will have produced a variety of steady-state inventories. Each inventory will have a corresponding set of policies, with resultant costs. If all the derived inventories are assumed to be equally effective, then it is only necessary to select the force structure with the lowest cost. But previous tasks will not produce every conceivable steady-state inventory. Instead, a variety of steady-state inventories that exhibit the effect of selected variations in the policy variables will be produced. To obtain the best possible result, the information in the various inventories must be used to understand how steady-state force structure and resultant costs vary with the policy variables. If such an analysis is successful, it should be possible to obtain a least-cost force structure by analytic or computational techniques. For example, a number of steady-state inventories could be produced based on variations in time-in-service requirements for promotions. Such inventories would presumably exhibit, *inter alia*, differing promotion opportunities, average times to advancement, and personnel costs. It may be possible to derive some precise relationships between the above variables, leading to an understanding of how far time-in-service requirements for promotion can be varied without adversely affecting promotion opportunities and personnel costs.

Finally, a philosophical issue has importance for this work. The Navy is by nature and for good reason a conservative organization. It is averse to risk and avoids policies that might threaten personnel readiness. The steady-state inventories will be based on statistical estimates of behavior. Such estimates are not exact and are subject to typical confidence intervals. The consequences of errors in estimates are asymmetric, in the sense that an excess of personnel leads to unnecessary costs, whereas a shortage of personnel threatens national security. In such a context, it appears sensible to build some risk-aversion techniques into the analytic process. This can be approached in a variety of ways. First, the techniques of decision making under uncertainty may be integrated into the work. This may lead to a force structure that is not the cheapest, but may be more readily attained when personnel behavior patterns are not as expected. A second risk-averse approach to personnel management is to establish policies that allow the Navy to adjust to fluctuations in inventory. For example, a significant number of shore billets may be filled by any petty officer (recruiting billets, etc.). It is not apparent how to fill these billets from the various skills, and it may be desirable to allow for variations in the manner in which such billets are filled. This is because inventory fluctuations may lead to either overmanning or undermanning of shore billets in individual skills. General shore billets provide a means to adjust to such fluctuations by reapportioning the billets appropriately. A concept of "slack" seems appropriate in describing the desirability of items such as general shore billets: they provide Navy management the slack required for day-to-day management. Hopefully, it will be possible to attain a more quantitative measure of the value of "slack."

REFERENCES

- [1] NAVPERS Instruction 15909D, *Enlisted Transfer Manual*, Sep 1988
- [2] CNA Research Memorandum 88-218, *Mathematical Relationships Between Pay Grade Structure, Longevity, and Promotion Policy*, David Rodney, Dec 1988 (27880218)¹

1. The number in parentheses is an internal CNA control number.